1.2 Early Life

Figure C1.9: An outcrop of ancient sedimentary rock is one of the highlights of Cameron Falls.

- sedimentary rock: rock formed from compressed layers of pre-existing rock or organic matter
- fossil: the evidence or remains of ancient life preserved in Earth's crust
- strata: the layered bands within sedimentary rock

Cameron Falls is a popular sightseeing spot in Waterton Lakes National Park, which is located in southwestern Alberta. In Figure C1.9 you can see a stunning outcrop of Alberta's oldest **sedimentary rock**. You can see layer upon layer of sediment compressed into solid rock. The properties of the sediments, and the **fossils** preserved in each **strata**, provide evidence about the type of environment that existed when they were deposited 1.5 billion years ago.

An Ancient Coast

By studying the processes that form sedimentary rocks in the present, geologists suspect the sediment that formed the layers at Cameron Falls must have been deposited at the mouth of a river flowing into an ancient ocean. Similar Precambrian sedimentary rock formations along the Rocky Mountains indicate that several large rivers deposited sand, clay, and silt into an ancient ocean. A sandwich of sedimentary rock 11 km thick is currently evident.

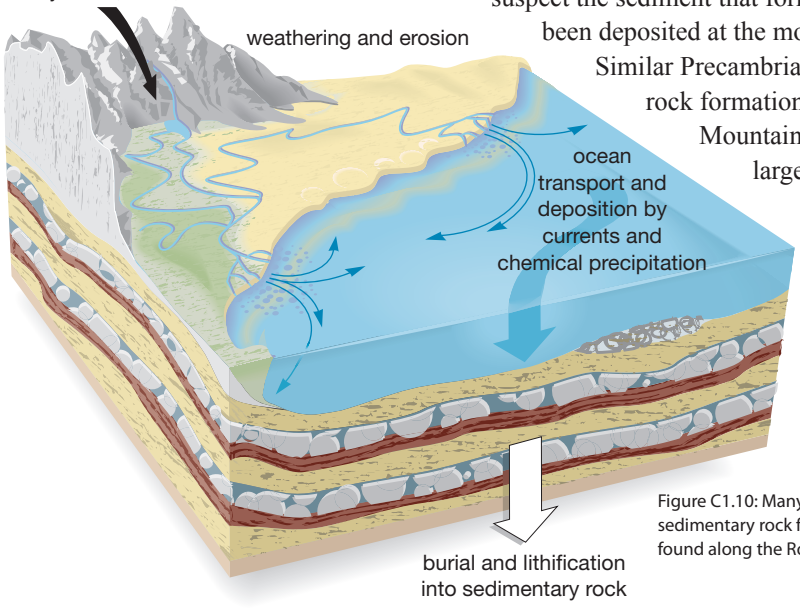
land transport and deposition by water, wind, and ice
weathering and erosion
ocean transport and deposition by currents and chemical precipitation
burial and lithification into sedimentary rock

Figure C1.10: Many Precambrian sedimentary rock formations have been found along the Rocky Mountains.

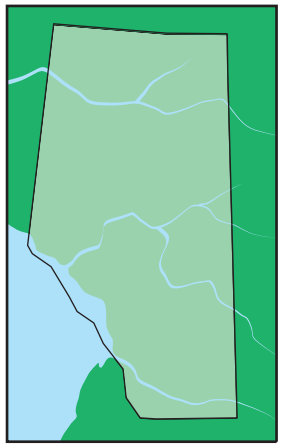

Figure C1.11: Alberta may have looked like this 1.5 billion years ago.

DID YOU KNOW?

Geologists in the nineteenth century attempted to measure the age of Earth by using rates of sedimentation. They theorized the sediment was like sand falling through an hourglass. If you knew the thickness of the sedimentary rock and the rate of sedimentation, you could calculate how long the rock took to form. More than 100 years ago, geologists attempted to determine the age of rocks—and even the age of Earth itself—by using rates of sedimentation. Their calculations did yield numbers in the millions of years, opening the door for the theory of deep time. But these scientists were nowhere near the current value of 4.5 billion years. The assumptions upon which the calculations were based just didn't hold up.

Practice

4. A geologist finds that a present-day river, similar in size to the one thought to have existed at Cameron Falls 1.5 billion years ago, deposits sediment at a rate of 1.0 cm/a. Use this measurement to calculate the time it took to deposit Alberta's 11-km thick sandwich of Precambrian sedimentary rock strata.
5. List assumptions you have to make to perform the calculation in question 4.

Life Gets Its Start

Before looking at the fossil evidence for early life in the rock layers at Cameron Falls, you should consider the evidence from even older fossils found in other places. The world's oldest evidence of life dates back 3.8 billion years. Life may have existed before that, but there is no fossil evidence to support this. Although there is still plenty of debate within the scientific community concerning just how and when life began on Earth, scientists generally agree that the earliest life forms were single-celled bacteria approximately 3.8 billion years ago.

3.8 billion years ago: first sign of life on Earth

- stromatolite: a layered structure built by cyanobacteria
- cyanobacteria: microscopic, photosynthetic, single-celled bacteria

Hot Oceans

Early Earth was a hostile place, with frequent volcanic eruptions and poisonous gases, such as methane and hydrogen sulfide. The oceans were extremely hot—more than 100°C—and the atmosphere contained little oxygen. At one time, scientists believed that life under these conditions would have been impossible. But recent studies of current, similar environments have revealed a group of extreme bacteria-like organisms that tolerate the heat and live on poisonous gases.

One of the first discoveries of these creatures, now called *Archaea*, was in the boiling waters of a hot spring in Yellowstone National Park. (See Figure C1.12.) Later, similar creatures were found living in water exceeding 150°C near deep-sea thermal vents.

Figure C1.12: Scientists are sampling a volcanically heated pool for Archaea.

Deep-sea thermal vents release intense volcanic heat and hydrogen sulfide gas. Despite these hostile conditions, the *Archaea* organisms living near these vents thrive by feeding on the hydrogen sulfide—a gas deadly to humans. This group of extremist life forms may be the closest living relatives of Earth's earliest life.

Making the Atmosphere Breathable

When the layers of rock at Cameron Falls started to form 1.5 billion years ago, the surrounding area was thought to be a large, shallow mud flat where a large river drained into an ancient ocean. Fossil evidence in the form of **stromatolites** indicates that **cyanobacteria** lived in the tropically warm, shallow waters along the coast of ancient Alberta.

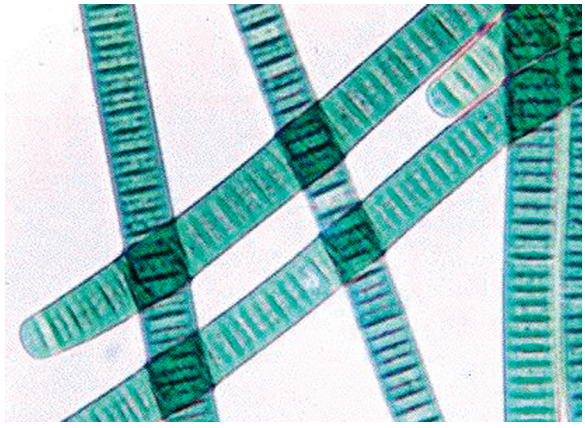

Figure C1.13: Cyanobacteria are single-celled creatures similar to Earth's first photosynthetic organisms.

By growing and dying one layer on top of the other, the cyanobacteria slowly deposited layer after layer of calcium carbonate—the main ingredient of limestone and your bones—leaving large mounds, called stromatolites, that are 10 to 30 cm across and up to 1 m tall. Stromatolites are the remains of the calcium carbonate layers, not the cyanobacteria themselves. This makes stromatolites an example of a **trace fossil**.

trace fossil: indirect fossilized evidence left by ancient organisms rather than the organisms themselves

Figure C1.14: Alberta's oldest fossils are stromatolites.

1.5 billion years old: Alberta's oldest fossils

A Source of Oxygen

Cyanobacteria, such as those that built Alberta's stromatolites, played a key role in making Earth livable for other organisms. Scientists believe that they were one of the only early producers of oxygen. The earliest direct evidence of cyanobacteria—found at Isua Rock in Greenland—dates back 3.7 billion years. Cyanobacteria may have been the first organisms to use a complex molecule, called chlorophyl, to trap the Sun's energy, which is needed to make glucose out of carbon dioxide and water.

Practice

6. Identify the process that uses the Sun's energy to make glucose from carbon dioxide and water.
7. Refer to question 6. Identify the by-product of the process.

Stromatolites and other fossil evidence indicate that cyanobacteria were the dominant form of life on Earth for two billion years. Despite the microscopic size of each individual, these creatures have collectively had a tremendous impact on the whole planet because they are largely responsible for creating Earth's atmospheric oxygen. Some people would argue that the creation of today's oxygen-rich atmosphere is one of the most significant events in geological time.

This is due to the atmosphere's impact on the evolution of future life and because of the spinoff effects on the planet's geology. In the next investigation you will have an opportunity to explore the impact of Earth's oxygen-rich atmosphere on geological phenomena.

Investigation

The Early Atmosphere

Science Skills

✓ Analyzing and Interpreting

Problem

What does banded iron tell you about oxygen in Earth's atmosphere during the Precambrian Era?

Read the following background information.

Banded Iron Formations: Indicators of Oxygen

A type of iron ore, called banded iron, is instantly recognizable for its alternating layers of red and grey. It's of special interest to the mining industry as a source of iron to make steel. Banded iron is a sedimentary rock formed by sediment sinking to the bottom of an ocean. Banded iron formations from around the world range in age from 1.8 billion years to 3.8 billion years. The red layers contain iron (III) oxide, $Fe_2O_3(s)$, commonly called rust. The grey layers contain silica and other minerals.

The iron (III) oxide found in the red layers is produced by dissolved iron ions that have been weathered from continental rocks and carried by a river to the ocean. If oxygen is present, the iron ions react with it to form an oxide of iron.

$$4Fe^{3+}(aq) + 3O_2(g) \text{ Æ } 2Fe_2O_3(s)$$

Iron oxide is an insoluble precipitate and sinks to the bottom of the ocean as part of the sediment. Iron oxide forms when oxygen is present. This results in the red layers in the banded iron. Iron oxide does not form when oxygen is not present. This results in the formation of grey layers. Therefore, iron acts as a chemical indicator of oxygen in Earth's early atmosphere.

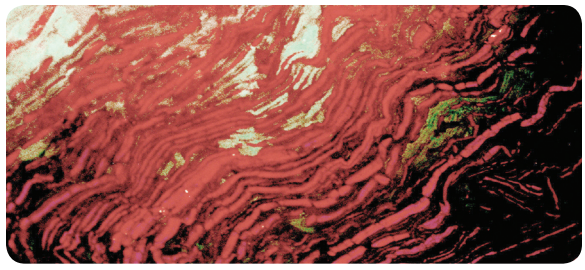

Figure C1.15: Banded iron is a sedimentary rock.

Analysis

1. Identify the likely source of oxygen required to form the iron (III) oxide found in red layers of banded iron formations.
2. The oldest banded iron formations are 3.8 billion years old. Rock layers below these do not contain iron (III) oxide.
   a. Infer what this suggests about the oxygen level in Earth's atmosphere before the banded iron was deposited.
   b. Banded iron formations of less than 1.8 billion years old are extremely rare. Sedimentary rock layers deposited on top are all rich in iron oxide, but there is no evidence of the striped iron bands. Conclude what this evidence suggests about atmospheric oxygen after the banded iron was deposited.
   c. Describe the atmospheric oxygen levels during the time of banded iron formations.

Snowball Earth

Late in the Precambrian Era, early life barely survived during the most significant ice age ever. Icecaps covered most of the planet for nearly ten million years. This time period is often called "Snowball Earth." The oceans froze solid except for small pockets of water that stayed in liquid form due to heat escaping from Earth's mantle. Evidence of glaciers advancing and retreating is found in late Precambrian rocks all over the world, including Alberta's Rocky Mountains. Some scientists believe that the stresses placed upon organisms as the result of changes in their habitat during this deep freeze, and the thaw that followed, may have resulted in an explosion in species diversity that led to the first complex creatures.

1.2 Summary

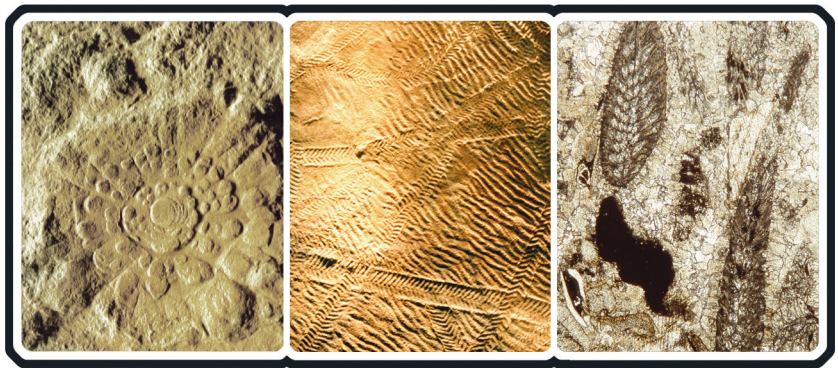

Figure C1.16: The fossils (from left) are of jellyfish, worm-shaped animals, and ferns.

By the end of the Precambrian Era, nearly 90% of Earth's history had passed. Earth had been born out of clouds of dust. The first producers, cyanobacteria, transformed the atmosphere. They left behind stromatolite mounds and banded iron deposits as indirect evidence of their existence. Direct evidence, such as fossil imprints found in the Rocky Mountains, reveals that stromatolites now shared their shallow waters with multicellular creatures, like small jellyfish, worm-shaped animals, and early plants. Life had taken a long time to start. Finally, the stage was set for the next major section of time —the Paleozoic Era—initiated by an explosion of new and bizarre creatures that populated Alberta's shoreline.

1.2 Questions

Knowledge

1. Describe how sedimentary rocks form.
2. Outline the significance of Alberta's Precambrian sedimentary rock formations.
3. Summarize the evidence that present-day Alberta was a hot, tropical, coastal area 1.5 billion years ago.
4. Describe Earth's first living creatures.
5. How old are the earliest signs of life?
6. Describe the environment in which Earth's first creatures lived.
7. Describe Alberta's oldest fossils. What did they look like? How were they built?

Applying Concepts

Figure C1.17: These geologists are standing by ancient sedimentary rock in Namibia.

8. Figure C1.17 shows two geologists posing by a 700 million-year-old sedimentary rock in Namibia. These big, embedded rocks are the type that glaciers pick up and carry with them as they flow. These types of glacial deposits are found in many parts of the world in rocks of this time period.
   a. Define the climate theory supported by these global glacial deposits.
   b. Just above the geologists' hands are sedimentary layers of limestone known only to be deposited in warm seas. What do these limestone deposits indicate?